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FIG.1

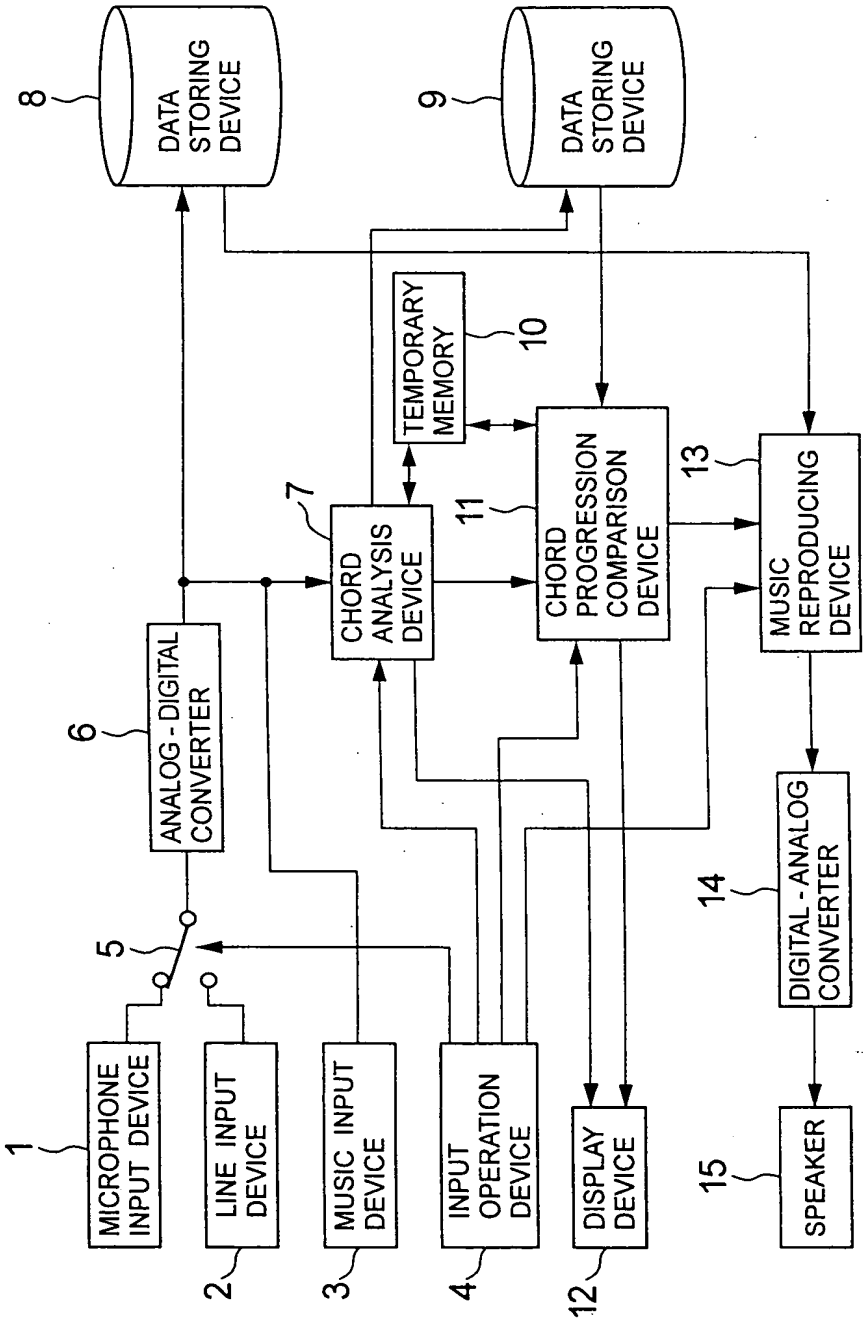

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FIG.2

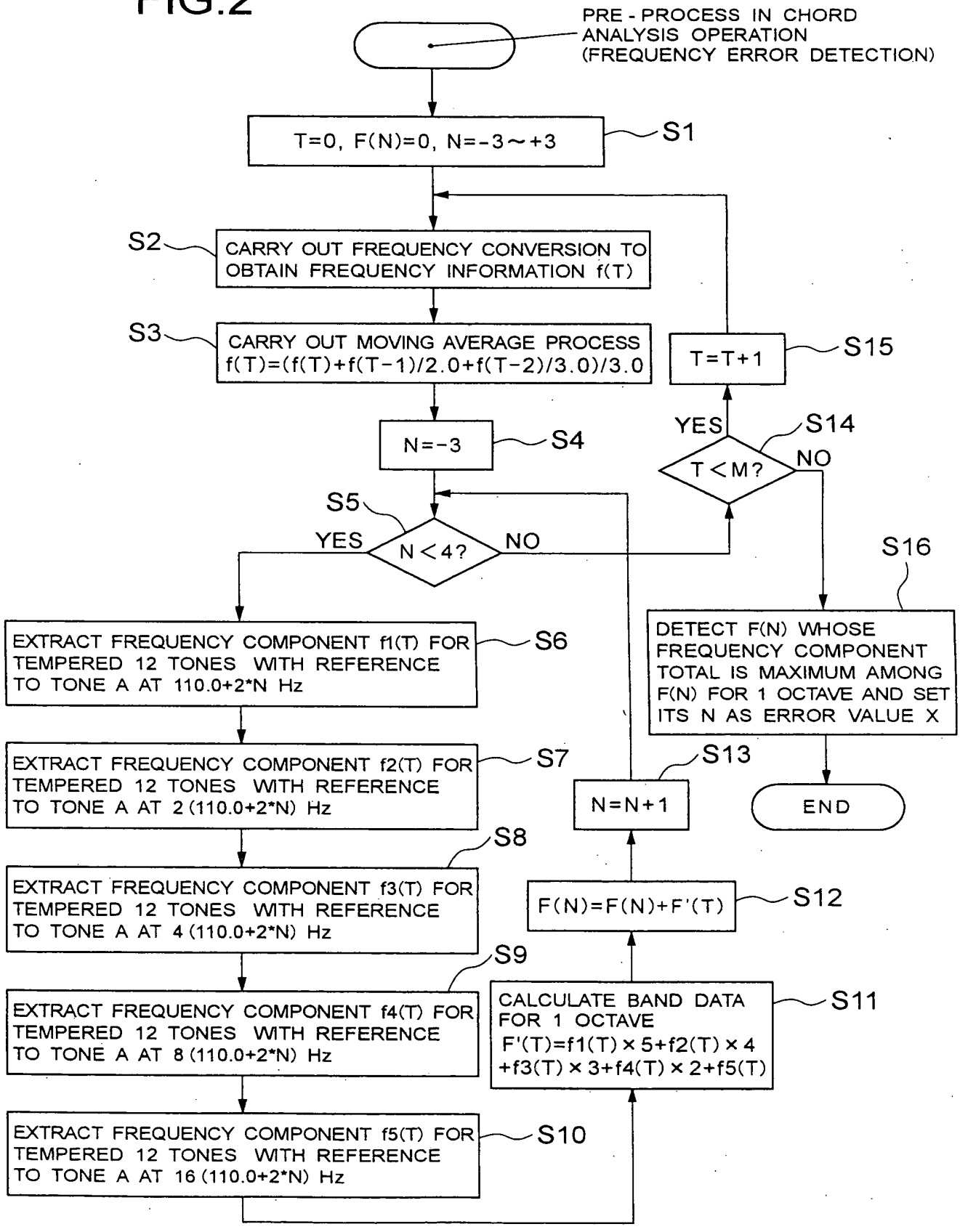
PRE-PROCESS IN CHORD ANALYSIS OPERATION (FREQUENCY ERROR DETECTION)
T=0, F(N)=0, N=-3~+3
S1
S2
CARRY OUT FREQUENCY CONVERSION TO OBTAIN FREQUENCY INFORMATION f(T)
S3
CARRY OUT MOVING AVERAGE PROCESS f(T)=(f(T)+f(T-1)/2.0+f(T-2)/3.0)/3.0
N=-3
S4
S5
YES
N<4?
NO
EXTRACT FREQUENCY COMPONENT f1(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 110.0+2*N Hz
S6
EXTRACT FREQUENCY COMPONENT f2(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 2(110.0+2*N) Hz
S7
EXTRACT FREQUENCY COMPONENT f3(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 4(110.0+2*N) Hz
S8
EXTRACT FREQUENCY COMPONENT f4(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 8(110.0+2*N) Hz
S9
EXTRACT FREQUENCY COMPONENT f5(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 16(110.0+2*N) Hz
S10
CALCULATE BAND DATA FOR 1 OCTAVE
F'(T)=f1(T)×5+f2(T)×4+f3(T)×3+f4(T)×2+f5(T)
S11
F(N)=F(N)+F'(T)
S12
N=N+1
S13
YES
T<M?
NO
S14
T=T+1
S15
DETECT F(N) WHOSE FREQUENCY COMPONENT TOTAL IS MAXIMUM AMONG F(N) FOR 1 OCTAVE AND SET ITS N AS ERROR VALUE X
S16
END

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FIG.3

A	1.0
A#	A × 1.059163
B	A × 1.124622
C	A × 1.189207
C#	A × 1.259921
D	A × 1.334840
D#	A × 1.414214
E	A × 1.498307
F	A × 1.587401
F#	A × 1.681793
G	A × 1.781797
G#	A × 1.887749
A	A × 2.0

FIG.4

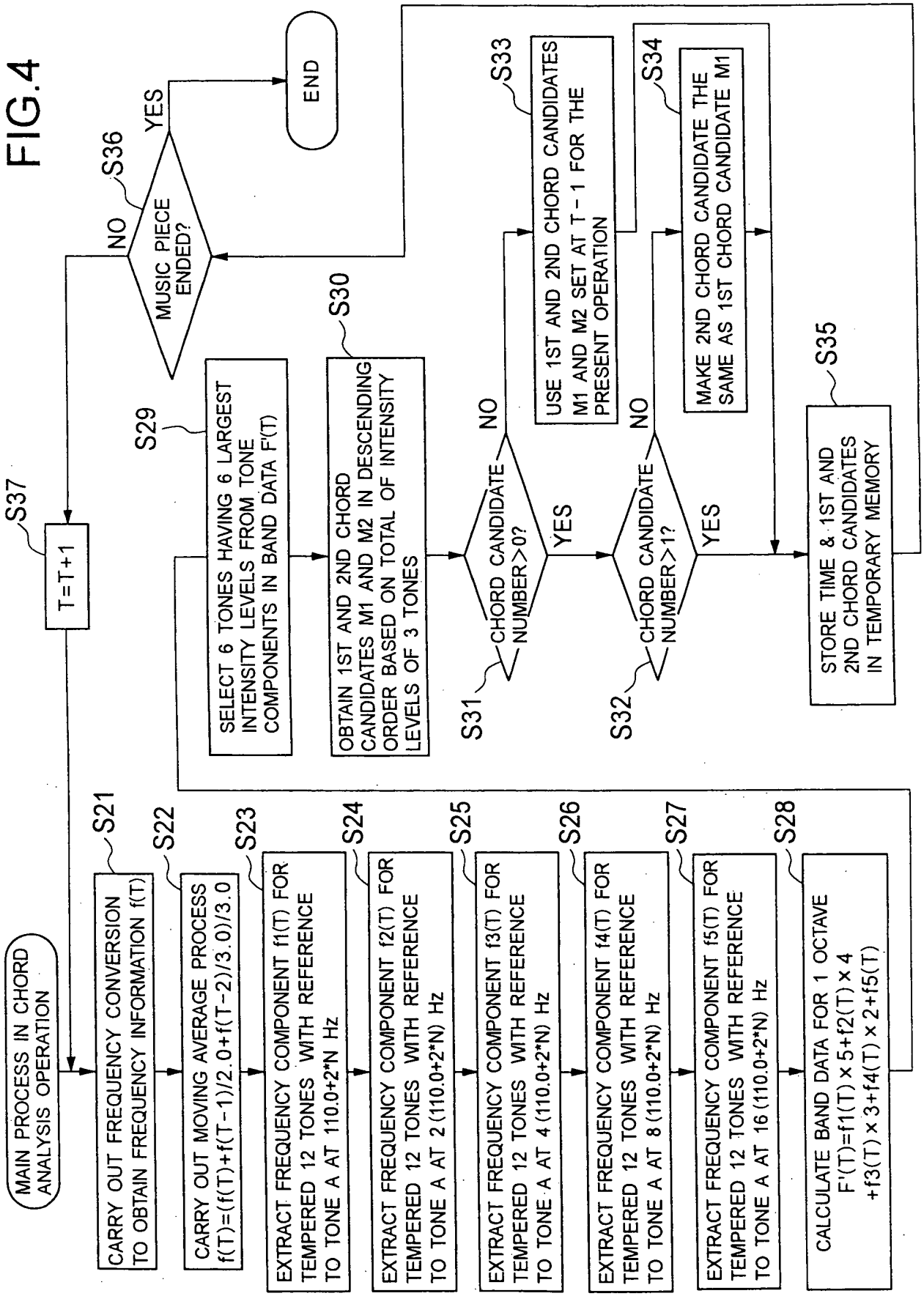
MAIN PROCESS IN CHORD ANALYSIS OPERATION
S21
CARRY OUT FREQUENCY CONVERSION TO OBTAIN FREQUENCY INFORMATION f(T)
S22
CARRY OUT MOVING AVERAGE PROCESS f(T)=(f(T)+f(T-1)/2.0+f(T-2)/3.0)/3.0
S23
EXTRACT FREQUENCY COMPONENT f1(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 110.0+2*N Hz
S24
EXTRACT FREQUENCY COMPONENT f2(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 2(110.0+2*N) Hz
S25
EXTRACT FREQUENCY COMPONENT f3(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 4(110.0+2*N) Hz
S26
EXTRACT FREQUENCY COMPONENT f4(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 8(110.0+2*N) Hz
S27
EXTRACT FREQUENCY COMPONENT f5(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 16(110.0+2*N) Hz
S28
CALCULATE BAND DATA FOR 1 OCTAVE F'(T)=f1(T)×5+f2(T)×4 +f3(T)×3+f4(T)×2+f5(T)
S29
SELECT 6 TONES HAVING 6 LARGEST INTENSITY LEVELS FROM TONE COMPONENTS IN BAND DATA F'(T)
S30
OBTAIN 1ST AND 2ND CHORD CANDIDATES M1 AND M2 IN DESCENDING ORDER BASED ON TOTAL OF INTENSITY LEVELS OF 3 TONES
S31
CHORD CANDIDATE NUMBER>0?
NO
YES
S32
CHORD CANDIDATE NUMBER>1?
NO
YES
S33
USE 1ST AND 2ND CHORD CANDIDATES M1 AND M2 SET AT T-1 FOR THE PRESENT OPERATION
S34
MAKE 2ND CHORD CANDIDATE THE SAME AS 1ST CHORD CANDIDATE M1
S35
STORE TIME & 1ST AND 2ND CHORD CANDIDATES IN TEMPORARY MEMORY
S36
MUSIC PIECE ENDED?
NO
YES
END
S37
T=T+1

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FIG.5

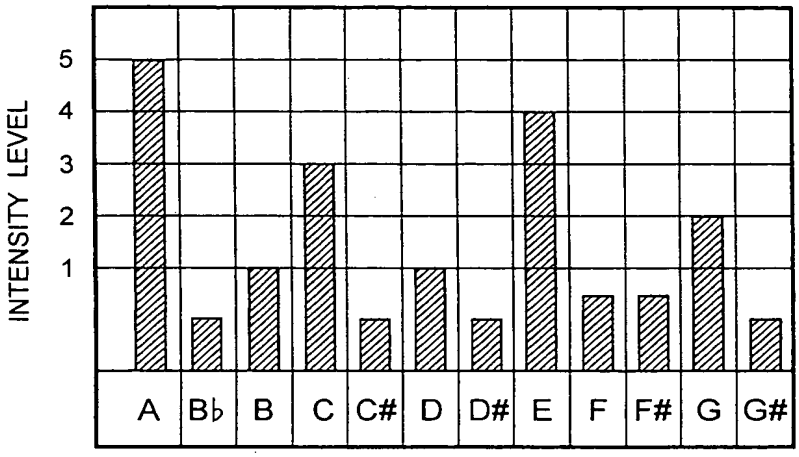

FIG.6

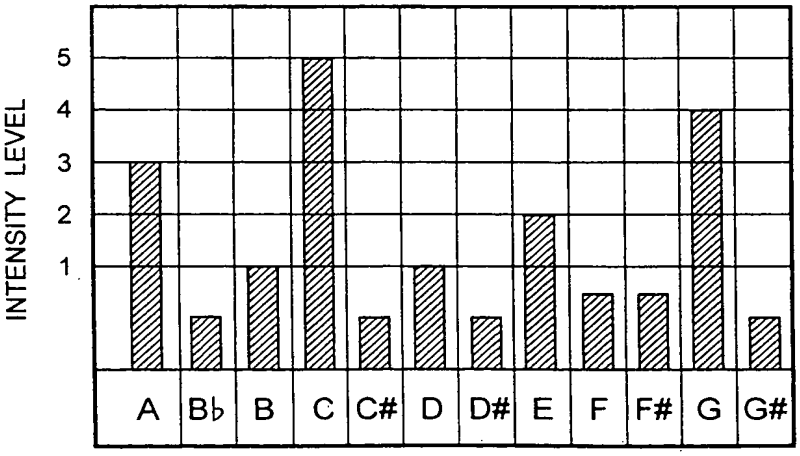

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FIG.7

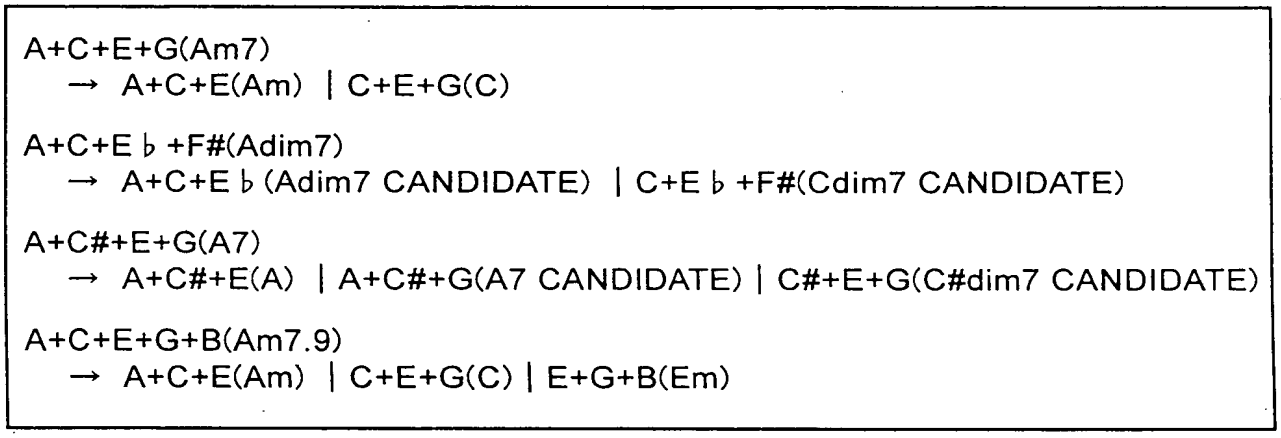
A+C+E+G(Am7)
→ A+C+E(Am) | C+E+G(C)
A+C+E♭+F#(Adim7)
→ A+C+E♭(Adim7 CANDIDATE) | C+E♭+F#(Cdim7 CANDIDATE)
A+C#+E+G(A7)
→ A+C#+E(A) | A+C#+G(A7 CANDIDATE) | C#+E+G(C#dim7 CANDIDATE)
A+C+E+G+B(Am7.9)
→ A+C+E(Am) | C+E+G(C) | E+G+B(Em)

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FIG.8

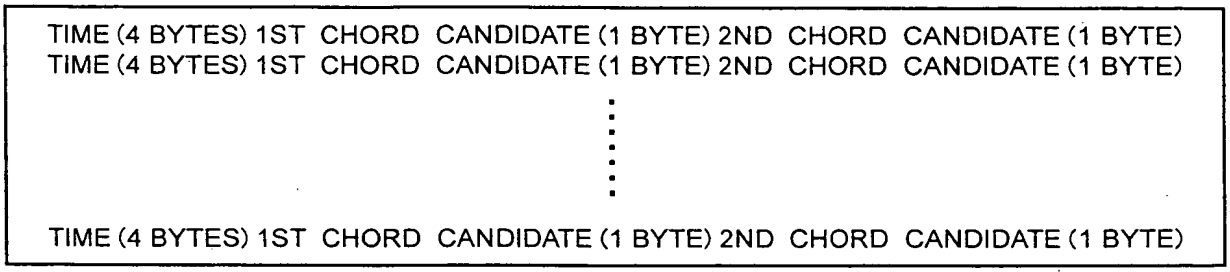

FIG.9A

FUNDAMENTAL TONE	
A	0 × 00
A#	0 × 01
B	0 × 02
C	0 × 03
C#	0 × 04
D	0 × 05
D#	0 × 06
E	0 × 07
F	0 × 08
F#	0 × 09
G	0 × 0A
G#	0 × 0B

FIG.9B

ATTRIBUTE	
MAJOR	0 × 00
MINOR	0 × 02
7TH CANDIDATE	0 × 01
DIM 7TH CANDIDATE	0 × 03

FIG.9C

ATTRIBUTE (LOWER 4 BITS) + FUNDAMENTAL TONE (LOWER 4 BITS)

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FIG.10

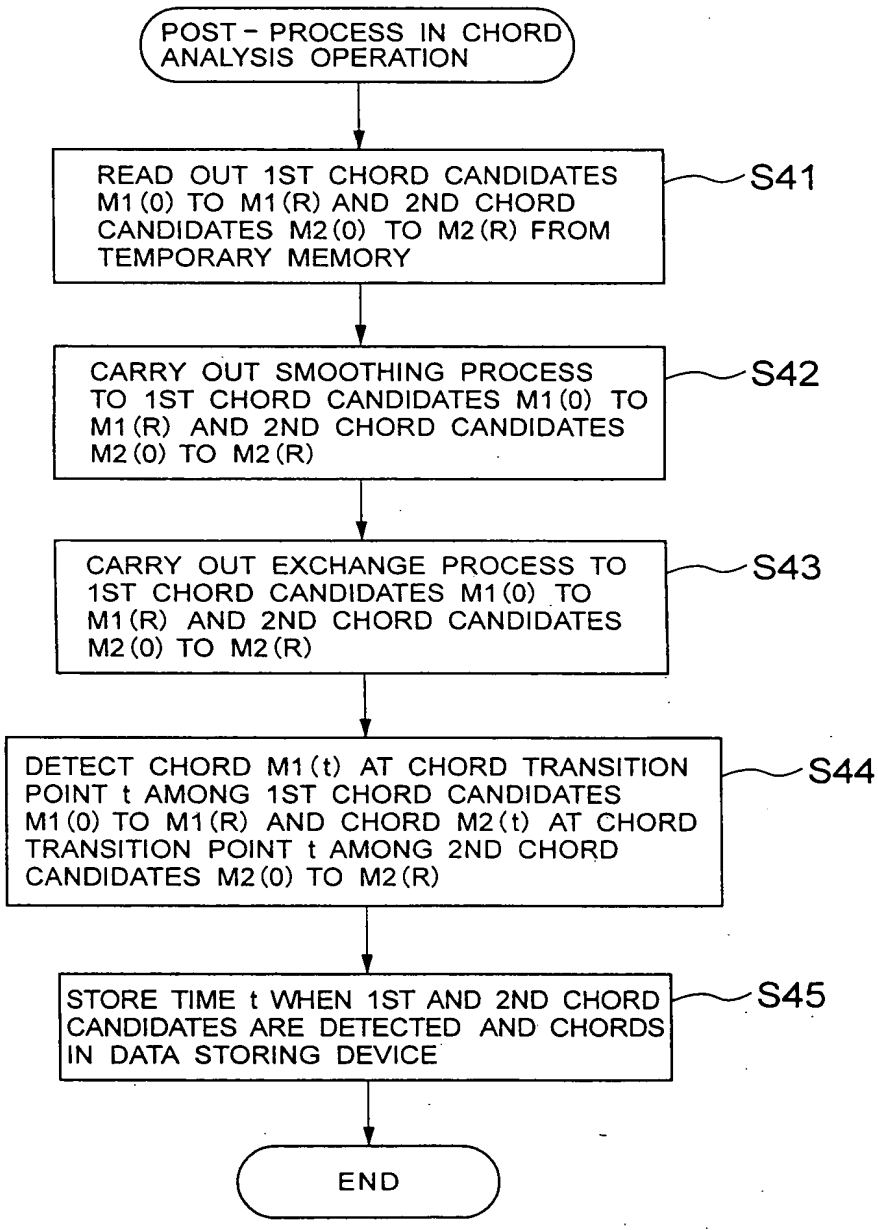
POST - PROCESS IN CHORD ANALYSIS OPERATION
READ OUT 1ST CHORD CANDIDATES M1(0) TO M1(R) AND 2ND CHORD CANDIDATES M2(0) TO M2(R) FROM TEMPORARY MEMORY
S41
CARRY OUT SMOOTHING PROCESS TO 1ST CHORD CANDIDATES M1(0) TO M1(R) AND 2ND CHORD CANDIDATES M2(0) TO M2(R)
S42
CARRY OUT EXCHANGE PROCESS TO 1ST CHORD CANDIDATES M1(0) TO M1(R) AND 2ND CHORD CANDIDATES M2(0) TO M2(R)
S43
DETECT CHORD M1(t) AT CHORD TRANSITION POINT t AMONG 1ST CHORD CANDIDATES M1(0) TO M1(R) AND CHORD M2(t) AT CHORD TRANSITION POINT t AMONG 2ND CHORD CANDIDATES M2(0) TO M2(R)
S44
STORE TIME t WHEN 1ST AND 2ND CHORD CANDIDATES ARE DETECTED AND CHORDS IN DATA STORING DEVICE
S45
END

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FIG.11

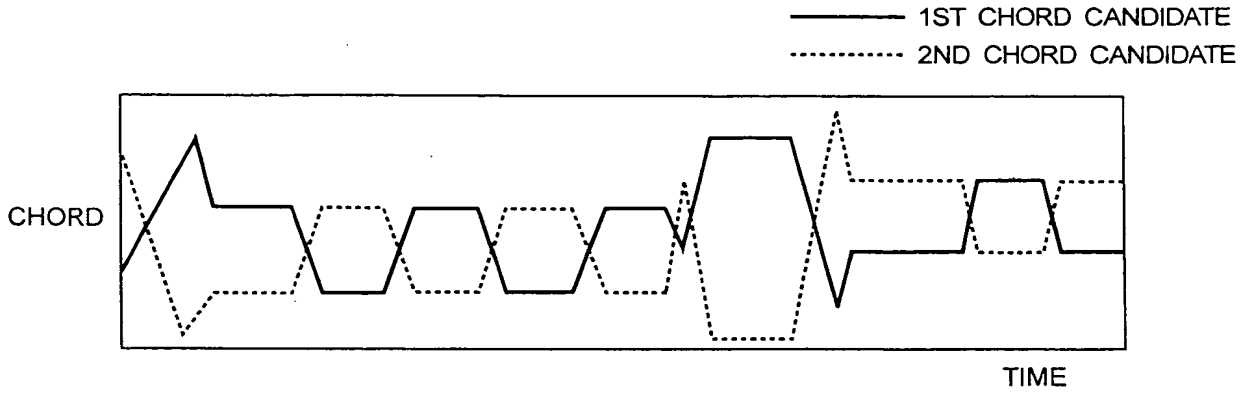

FIG.12

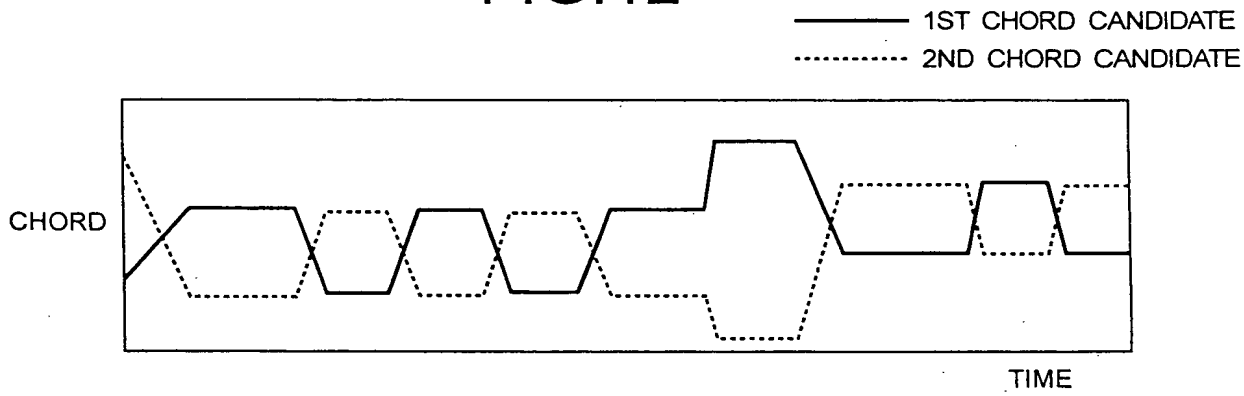

FIG.13

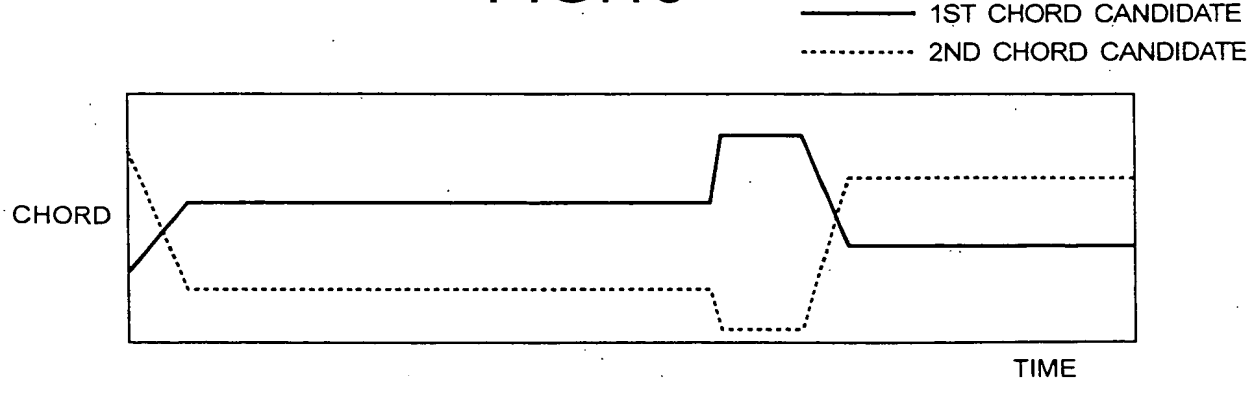

FIG.14A

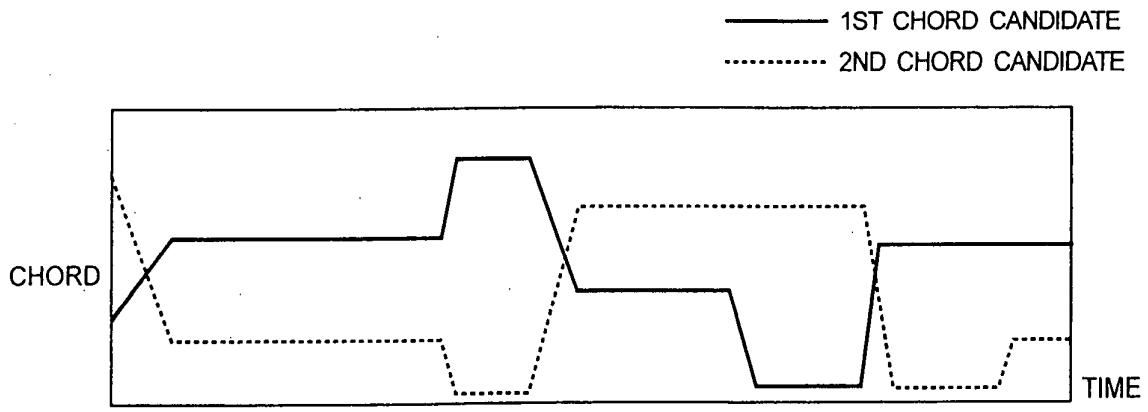

FIG.14B

TRANSITION OF 1ST CHORD CANDIDATE	F	G	D	B♭	F
	0×08	0×0A	0×05	0×01	0×08
	←TIME (T1(0))	T1(1)	T1(2)	T1(3)	T1(4)

FIG.14C

TRANSITION OF 2ND CHORD CANDIDATE	F	B♭	F#m	B♭	C
	0×03	0×01	0×29	0×01	0×03
	←TIME (T2(0))	T2(1)	T2(2)	T2(3)	T2(4)

FIG.14D

IDENTIFICATION INFORMATION FOR MUSIC PIECES (FILE NAMES, ETC.) (512 BYTES)

NUMBER OF 1ST CHORD CANDIDATES (4 BYTES) T1(0) (4 BYTES) [0×08] T1(1) (4 BYTES) [0×0A] T1(2) (4 BYTES) [0×05] T1(3) (4 BYTES) [0×01] T1(4) (4 BYTES) [0×08] ·····

NUMBER OF 2ND CHORD CANDIDATES (4 BYTES) T2(0) (4 BYTES) [0×03] T2(1) (4 BYTES) [0×01] T2(2) (4 BYTES) [0×29] T2(3) (4 BYTES) [0×01] T2(4) (4 BYTES) [0×03] ·····

REPLACEMENT SHEET

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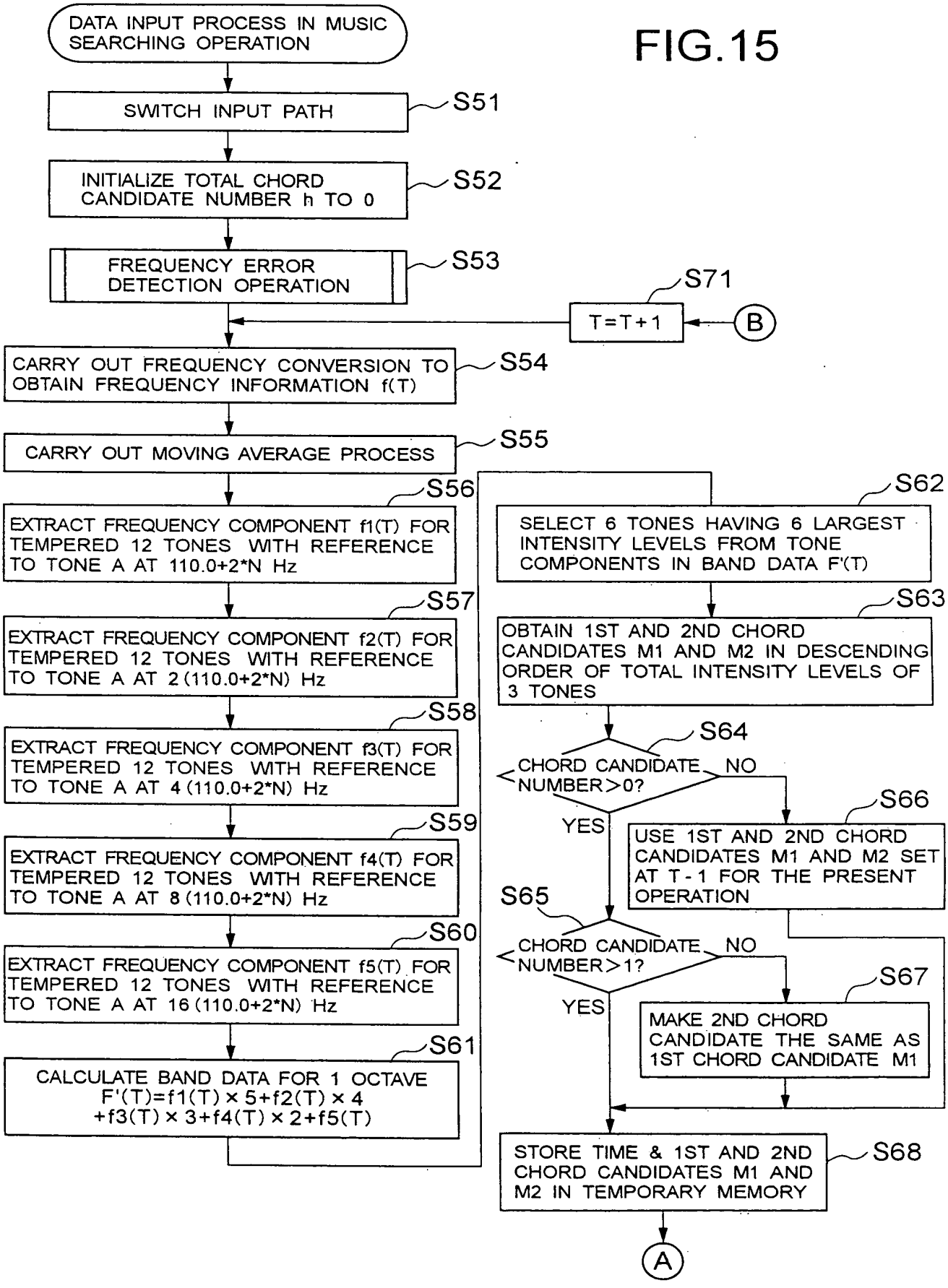
FIG.15


DATA INPUT PROCESS IN MUSIC SEARCHING OPERATION
SWITCH INPUT PATH
S51
INITIALIZE TOTAL CHORD CANDIDATE NUMBER h TO 0
S52
FREQUENCY ERROR DETECTION OPERATION
S53
S71
T=T+1
B
CARRY OUT FREQUENCY CONVERSION TO OBTAIN FREQUENCY INFORMATION f(T)
S54
CARRY OUT MOVING AVERAGE PROCESS
S55
S56
EXTRACT FREQUENCY COMPONENT f1(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 110.0+2*N Hz
S57
EXTRACT FREQUENCY COMPONENT f2(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 2(110.0+2*N) Hz
S58
EXTRACT FREQUENCY COMPONENT f3(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 4(110.0+2*N) Hz
S59
EXTRACT FREQUENCY COMPONENT f4(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 8(110.0+2*N) Hz
S60
EXTRACT FREQUENCY COMPONENT f5(T) FOR TEMPERED 12 TONES WITH REFERENCE TO TONE A AT 16(110.0+2*N) Hz
S61
CALCULATE BAND DATA FOR 1 OCTAVE
F'(T)=f1(T)×5+f2(T)×4
+f3(T)×3+f4(T)×2+f5(T)
S62
SELECT 6 TONES HAVING 6 LARGEST INTENSITY LEVELS FROM TONE COMPONENTS IN BAND DATA F'(T)
S63
OBTAIN 1ST AND 2ND CHORD CANDIDATES M1 AND M2 IN DESCENDING ORDER OF TOTAL INTENSITY LEVELS OF 3 TONES
S64
CHORD CANDIDATE NUMBER>0?
NO
YES
S66
USE 1ST AND 2ND CHORD CANDIDATES M1 AND M2 SET AT T-1 FOR THE PRESENT OPERATION
S65
CHORD CANDIDATE NUMBER>1?
NO
YES
S67
MAKE 2ND CHORD CANDIDATE THE SAME AS 1ST CHORD CANDIDATE M1
STORE TIME & 1ST AND 2ND CHORD CANDIDATES M1 AND M2 IN TEMPORARY MEMORY
S68
A

COPY

FIG.16

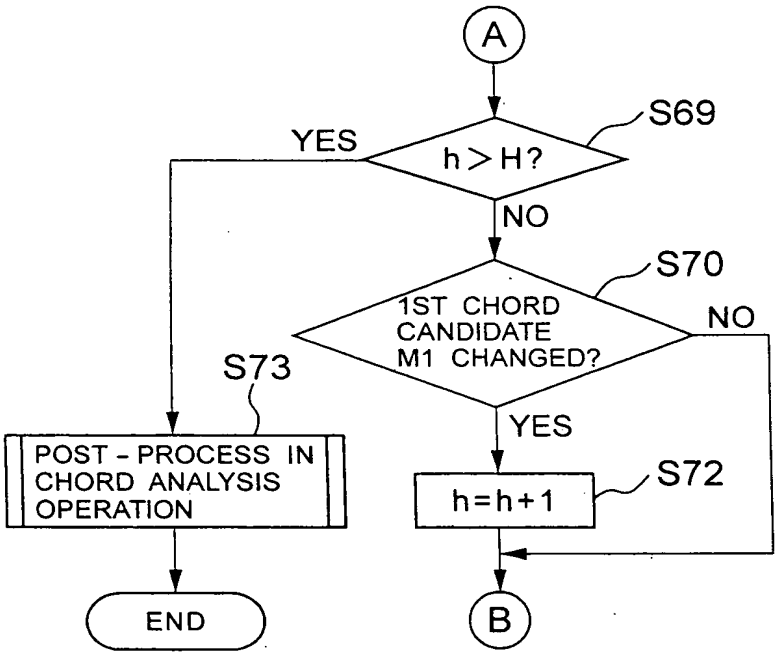

A
S69
YES
h > H?
NO
S70
1ST CHORD CANDIDATE M1 CHANGED?
NO
S73
YES
POST - PROCESS IN CHORD ANALYSIS OPERATION
S72
h=h+1
END
B

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FIG. 17

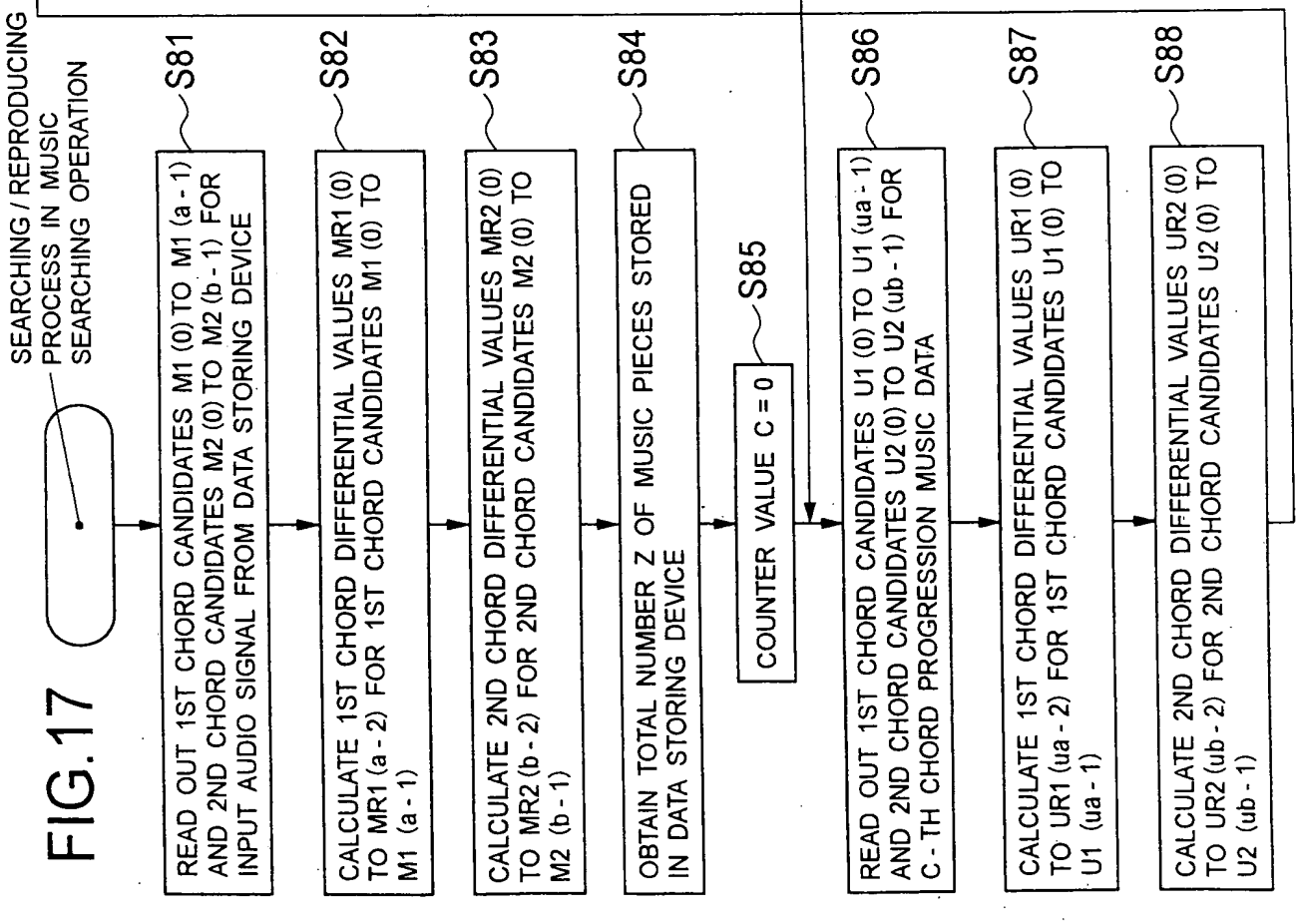
SEARCHING / REPRODUCING PROCESS IN MUSIC SEARCHING OPERATION
READ OUT 1ST CHORD CANDIDATES M1 (0) TO M1 (a - 1) AND 2ND CHORD CANDIDATES M2 (0) TO M2 (b - 1) FOR INPUT AUDIO SIGNAL FROM DATA STORING DEVICE
S81
CALCULATE 1ST CHORD DIFFERENTIAL VALUES MR1 (0) TO MR1 (a - 2) FOR 1ST CHORD CANDIDATES M1 (0) TO M1 (a - 1)
S82
CALCULATE 2ND CHORD DIFFERENTIAL VALUES MR2 (0) TO MR2 (b - 2) FOR 2ND CHORD CANDIDATES M2 (0) TO M2 (b - 1)
S83
OBTAIN TOTAL NUMBER Z OF MUSIC PIECES STORED IN DATA STORING DEVICE
S84
COUNTER VALUE C = 0
S85
READ OUT 1ST CHORD CANDIDATES U1 (0) TO U1 (ua - 1) AND 2ND CHORD CANDIDATES U2 (0) TO U2 (ub - 1) FOR C - TH CHORD PROGRESSION MUSIC DATA
S86
CALCULATE 1ST CHORD DIFFERENTIAL VALUES UR1 (0) TO UR1 (ua - 2) FOR 1ST CHORD CANDIDATES U1 (0) TO U1 (ua - 1)
S87
CALCULATE 2ND CHORD DIFFERENTIAL VALUES UR2 (0) TO UR2 (ub - 2) FOR 2ND CHORD CANDIDATES U2 (0) TO U2 (ub - 1)
S88
CARRY OUT CROSS - CORRELATION OPERATION BETWEEN CHORD PROGRESSION MUSIC DATA FOR INPUT AUDIO SIGNAL AND 1ST CHORD CANDIDATE FOR C - TH CHORD PROGRESSION MUSIC DATA TO CALCULATE CORRELATION COEFFICIENT COR (t) (INCLUDING JUMP PROCESS AND RELATED KEY PROCESS)
S89
OBTAIN MINIMUM VALUE COR_MIN (C) FOR CORRELATION COEFFICIENT COR (t)
S90
CARRY OUT CROSS - CORRELATION OPERATION BETWEEN CHORD PROGRESSION MUSIC DATA FOR INPUT AUDIO SIGNAL AND 2ND CHORD CANDIDATE FOR C - TH CHORD PROGRESSION MUSIC DATA TO CALCULATE CORRELATION COEFFICIENT COR (t) (INCLUDING JUMP PROCESS AND RELATED KEY PROCESS)
S91
OBTAIN MINIMUM VALUE MIN [COR (t)] FOR CORRELATION COEFFICIENT COR (t) FOR ADDITION TO COR_MIN (C)
S92
C=C+1
S93
C > Z+1?
S94
NO
YES
DISPLAY MUSIC INFORMATION AT DISPLAY DEVICE IN ASCENDING ORDER OF CORRELATION COEFFICIENT MINIMUM VALUES COR_MIN (0) TO COR_MIN (Z - 1) FOR MUSIC PIECES AT LIST
S95
OUTPUT PERFORMANCE SOUNDS OF MUSIC PIECE AT TOP OF LIST AS REPRODUCED SOUNDS
S96
END

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FIG.18

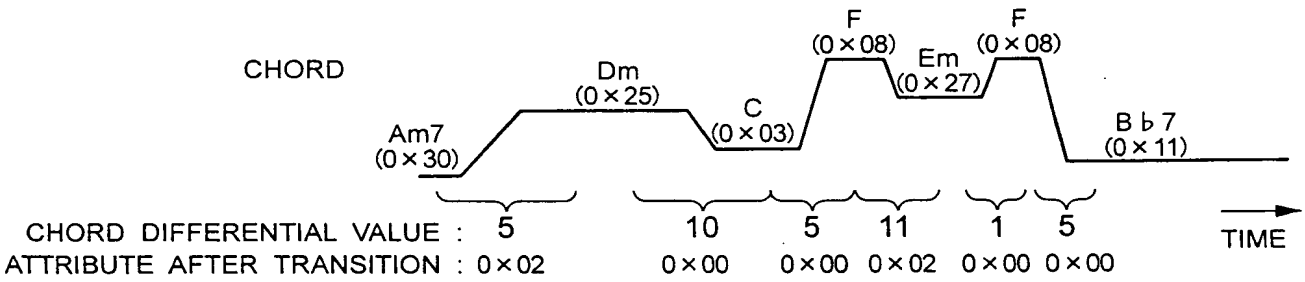
CHORD
Am7
(0×30)
Dm
(0×25)
C
(0×03)
F
(0×08)
Em
(0×27)
F
(0×08)
B♭7
(0×11)
CHORD DIFFERENTIAL VALUE : 5 10 5 11 1 5
ATTRIBUTE AFTER TRANSITION : 0×02 0×00 0×00 0×02 0×00 0×00
TIME

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FIG.19A

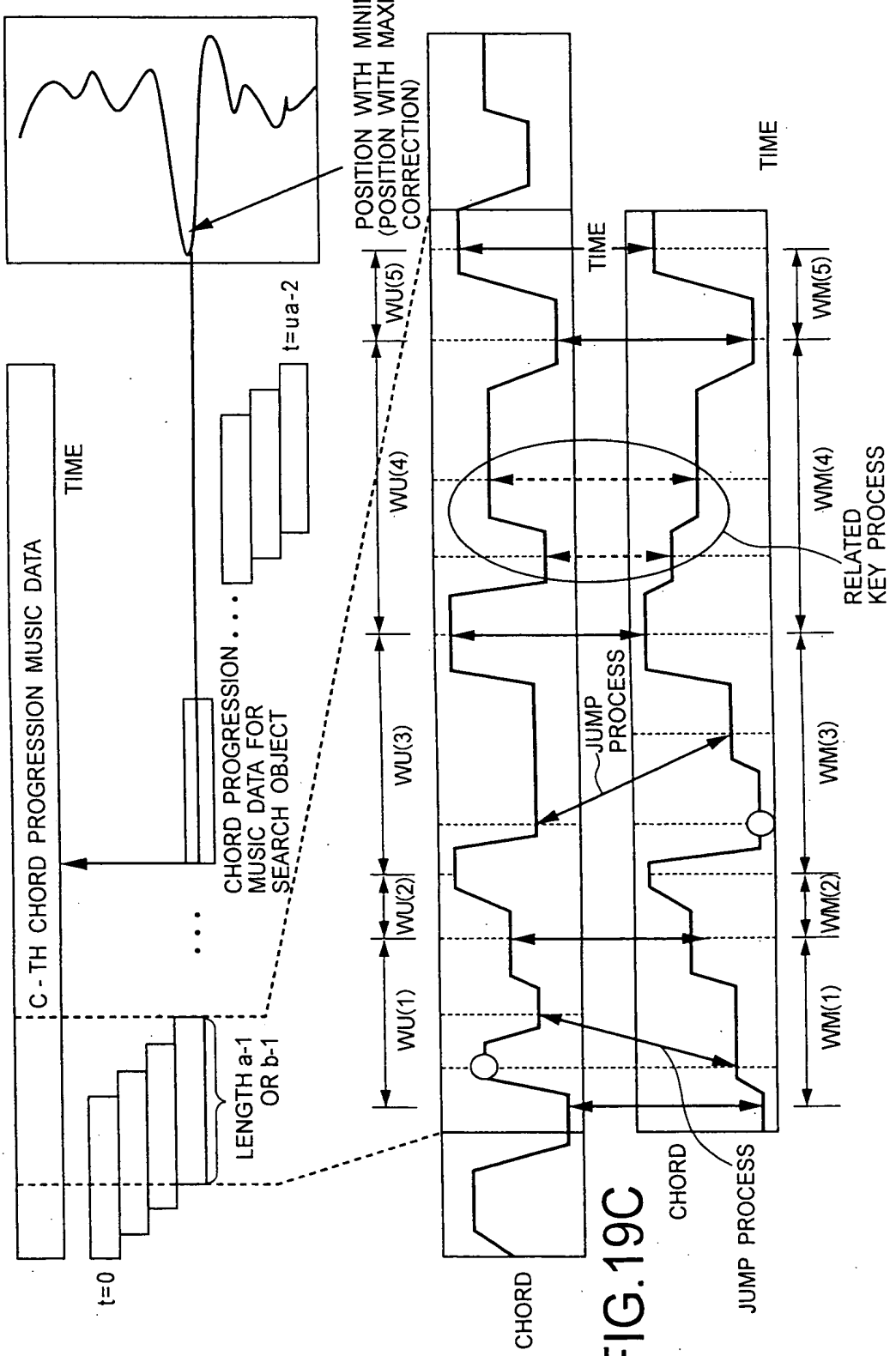

FIG.19B

FIG.19C

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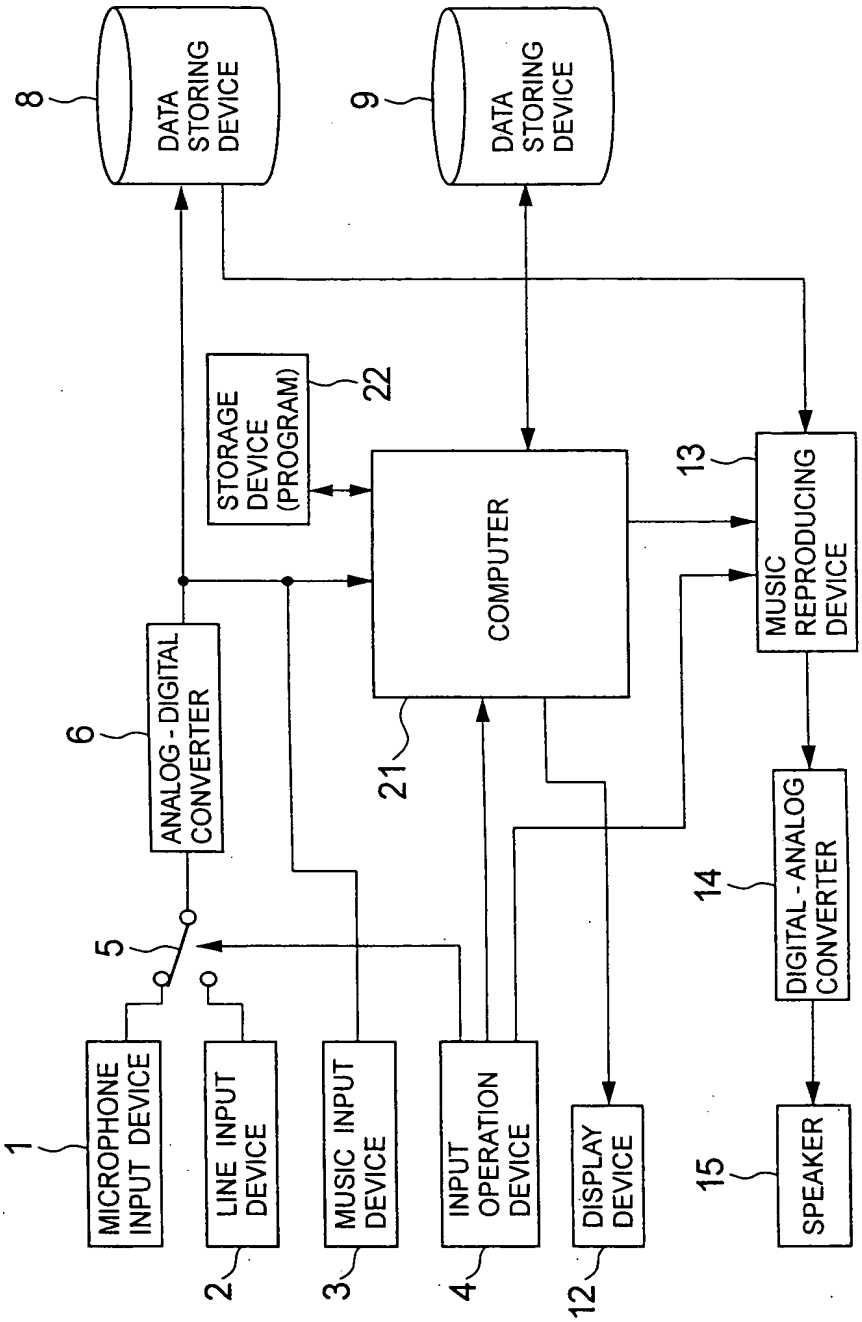
FIG.20


8
DATA STORING DEVICE
9
DATA STORING DEVICE
STORAGE DEVICE (PROGRAM)
22
COMPUTER
13
MUSIC REPRODUCING DEVICE
6
ANALOG - DIGITAL CONVERTER
21
5
14
DIGITAL - ANALOG CONVERTER
1
MICROPHONE INPUT DEVICE
LINE INPUT DEVICE
MUSIC INPUT DEVICE
INPUT OPERATION DEVICE
DISPLAY DEVICE
15
SPEAKER
2
3
4
12